ANALYSIS OF KINEMATIC AND COMPLIANCE OF PASSIVE SUSPENSION SYSTEM USING ADAMS CAR

[1]Nurzaki Ikhsan, [2]Rahizar Ramli, [3]Anuar Alias,
Faculty of Mechanical Engineering, UiTM Shah Alam,
40450 Shah Alam , Selangor
Email: nurzaki@salam.uitm.edu.my
Phone: +60192819252, Fax: +60355435160
[2]Department of Mechanical Engineering, Faculty of Engineering,
University of Malaya, 50603 Kuala Lumpur
[3]R&D Department, Perusahaan Otomobil National (PROTON)

ABSTRACT

Experimental approach is usually use as the way to develop or modify suspension system to obtain maximum ride comfort and handling characteristic. This approach is a time consuming process, costly, and may not guarantee the optimum solution. In this paper, a half-car body of actual suspension system based on PROTON WRM 44 P0-34 was model using multi-dynamic software, MSC/ADAMS-Car. There were total of 10 components for each front McPherson strut and rear Multilink suspensions that consist of different joint types and degree of freedom. The model were develop by defining the location of hard-point or coordinate before specific all the component characteristic and joint type. The complete suspension model is simulated using vertical-parallel and vertical-oppose movement test on MSC/ADAMS Car, same with the actual experimental parameter setup. The kinematic and compliance (K&C) of simulation is compared with the experimental data to verify the suspension model. It is expected that simulated and experimental produce the identical data pattern with very minimal percentage error. Further investigation can be done to improve or optimize the performance of the suspension system once the model is verified.

Keyword: Suspension modelling, MSC/ADAMS Car, vertical parallel movement test, vertical oppose movement test,

INTRODUCTION

Nowadays, automotive industry becomes a fastest industry growing around the world (S. J. Chikhale & S. P. Deshmukh, 2013). In order to improve handling and ride comfort of a vehicle, suspension system design is the main factor as it used to support the load, and protect the passenger by absorbing the shock and vibration (S.Pathmasharma, J.K.Suresh, P.Viswanathan & R.Subramanian, 2013). There were numerous studies have been conducted on the suspension simulation testing to investigate either the kinematic and compliance (K&C) or dynamic characteristic. Kinematics can be defined in general as the study of motion without reference to the mass or force. There were also studies about the suspension model characteristic on quarter, half and full vehicle model. (W. C. Mitchell, R. Simons, T. Sutherland & K. L. Michael, 2008). The suspension system would have a testing on the suspension test rig as in a way to develop or modify suspension component system to obtain great characteristic. This approach basically is time consuming, costly, required workmanship and might have an error due to human factor, thus may not guarantee the optimum solution. The aim of this study is to generate a fully working suspension model of the actual PROTON WRM 44 P0-34 McPherson strut type for front and Multilink type for rear suspension system and simulate using MSC/ADAMS Car software. However, since the actual suspension system already exist, and it is a need to model the suspension for further analysis, the model generated should verified first with some of experimental data. It will be compared with the value of toe change, camber change and caster change when subjected to the vertical parallel movement test and vertical oppose movement test, replicating as same with experimental setup conducted by PROTON.

In the following subsection, the methodology adopted for this study is discussed briefly including modelling of suspension system and simulation process. Finally detail discussion on the result and conclusion is present.

METHODOLOGY

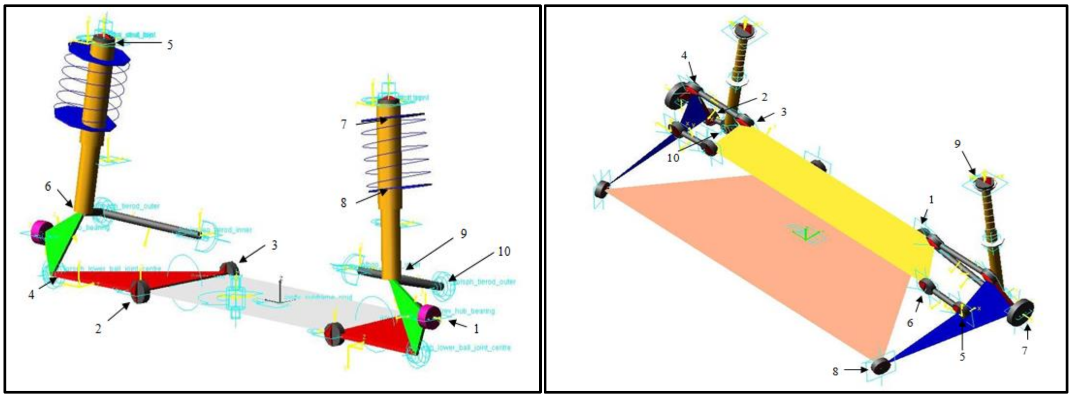
The process for this study involved several important steps. It start with modelling of a front half and rear half suspension system using MSC/ADAMS Car, employing simulation movement analysis test, and generate the K&C data for selected output for verification purpose.

Suspension Modeling On MSC/ADAMS Car

The multi body model of suspension systems are built using MSCADAMS/Car based on actual PROTON passenger car suspension system named as PROTON WRM 44 P0-34. As mentioned before, McPherson struts will be used for the front suspension system while Multilink suspension for the rear as shown in Figure 1.In order to replicate the actual suspension system, the model must be built using the same parameter as actual suspension such as hard points geometry, damper profiles (Figure 2), spring stiffness, antiroll bar stiffness, material selection of components, joining type and orientation and as well as bushing properties (H.A Attia, 2003). There were total of 10 components hard point in x, y, z direction for both suspension models with specific joining type and orientation.

The modelling stage is start by generating the suspension model template in the template view in MSC/ADAMS Car. This stage is important since it will determine the accuracy and working behavior of a suspension as an actual suspension. Once the template is done, it must save as a subsystem. At this point, not so much parameter can be change as template stage can do. There were four subsystems used for this study, which are McPherson suspension and front anti-roll bar for front suspension model and Multilink suspension and rear-anti roll bar for rear suspension model. Finally, the subsystems will be assembled as one working suspension system assembly. Note that, only complete assembly system can be analyze and testing using MSC/ADAMS Car (MSC/ADAMS Car User guide, 2003)

Table 1 and 2 shows the suspension individual component position and topology modelling for both suspensions. It shows the connectivity of each component with other components via joint type as well as the number of degree of freedom.



(a) (b)

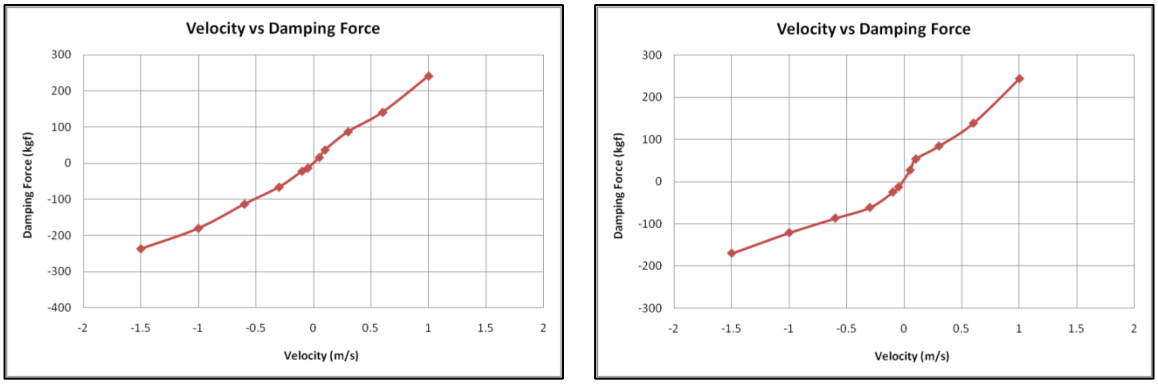
Figure 1. Suspension template model generated on MSC/ADAMS Car; (a) McPherson strut suspension (b) Multilink suspension

Table 1. Topology modeling for McPherson strut suspension system

Components	Connected Part	Joint	Degree of Freedom
Wheel Center	Wheel Carrier	Revolute Joint	1 Rotation
Lower Arm-Front	Body Sub-frame	Parallel Axes Joint	1 Translational,
Lower Arm-Rear	Body Sub-frame	Parallel Axes Joint	1 Translational,
Lower Arm-Outer	Wheel Carrier	Spherical Joint	3 Rotation
Strut-Top	Ground	Orientation Joint	3 Translational
Strut-Lower	Wheel Carrier	Translational Joint	1 Translational
Tierod-Outer	Wheel Carrier	Spherical Joint	3 Rotation
Tierod-Inner	Ground	Hooke Joint	2 Rotation
Spring center-upper	Strut	Translational joint	1 Translational
Spring center-lower	Strut	Translational joint	1 Translational

Table 2. Topology modeling for Multilink suspension system

Components	Connected Part	Joint	Degree of Freedom
Lower Arm-Inner	Ground	Parallel Axes Joint	1 Translational
Lower Arm-Outer	Trailing Arm	Implane Joint	2 Translational, 3 Rotation
Upper Arm-Inner	Ground	Parallel Axes Joint	1 Translational
Upper Arm-Outer	Trailing Arm	Implane Joint	2 Translational, 3 Rotation
Control Arm-Inner	Ground	Parallel Axes Joint	1 Translational
Control Arm-Outer	Trailing Arm	Implane Joint	2 Translational, 3 Rotation
Wheel Center	Wheel Carrier	Revolute Joint	1 Rotation
Trailing Arm	Ground	Inplane Joint	2 Translational, 3 Rotation
Strut-Top	Ground	Inline	1 Translational, 3 Rotation
Absorber To Lower Arm	Ground	Revolute Joint	1 Rotation

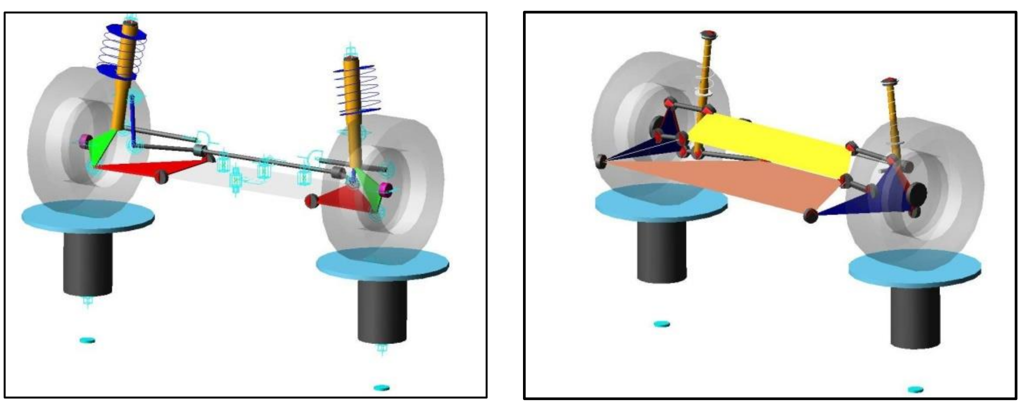


(a) (b)

Figure 2. Damper profile (a) McPherson strut suspension (b) Multilink suspension

Suspension Simulation

The suspension model simulation test is conducted using a suspension test rig (MDI_SDI_TESTRIG) on MSC/ADAMS Car (N. Xiaobin, Z. Cuiling, S. Jisheng, 2011). The method and procedure is same as the experimental setup. There were two type of simulation test for both front and rear suspension systems, which are, vertical parallel wheel movement test, where both of left and right wheels are subjected to the simultaneously parallel movement on the same vertical direction with 30 steps of 40mm bound and rebound travel (total of 80mm of wheel travel) value and vertical oppose wheel movement test where the wheel is subjected to the simultaneously oppose movement for the same steps and travel value.



(a) (b)

Figure 3. Complete suspension assembly simulation setup on MSC/ADAMS Car test rig (a) McPherson strut suspension (b) Multilink suspension

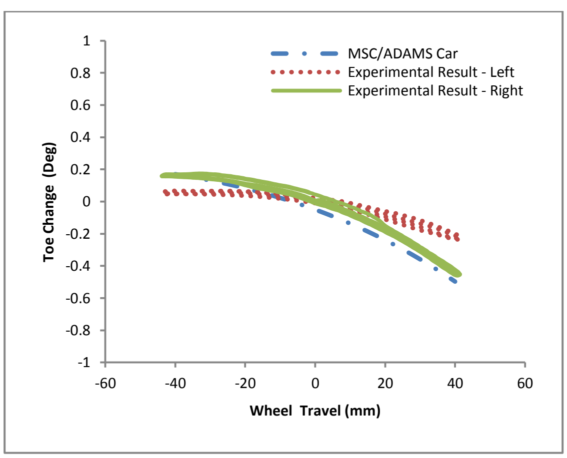
RESULTS AND DISCUSSION

Data Generated

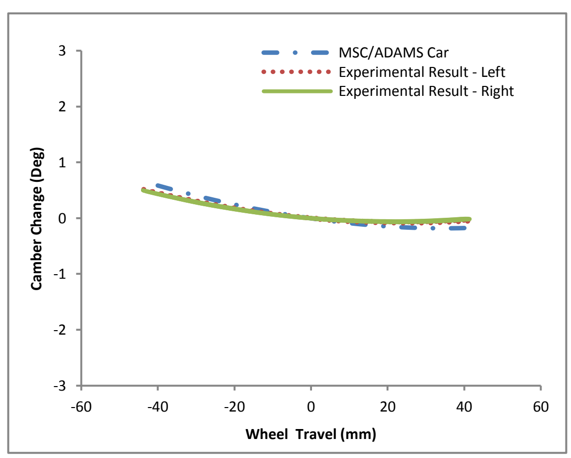
The simulation test generates a set of K&C data set. Using a post-processing window provided by MSC/ADAMS Car, all the necessary output can be tabulated. As mentioned before, only value of toe change, camber change and caster change to the wheel movement are considerate to compare with the experimental result since it gives significant effect of the overall K&C characteristic on static condition. Thus, there were 12 graphs generated. At the beginning stage of suspension modelling, the left and right side of suspension is set to be symmetry and having the same component properties to be simulated and tested. Thus, it doesn't matter to choose left or right data set to be compared with experimental result after simulation is done.The graphs are plotted in Figure 2 and 3 for vertical parallel wheel movement and vertical oppose wheel movement test respectively.

The analysis purpose is to verify the suspension model with the experimental. It clearly showed that all of the graphs, when compared, have an identical tabulated pattern as experimental result. However, some of the simulation data are not 100% having a same value when subjected to same wheel travel with experimental data. The maximum percentage error when the coefficient of determination for linear regression, R^2 is compared was on graph toe change for front suspension when subjected to vertical oppose wheel movement test, having 9.47% (Figure 3(a)). The minimum percentage error is 0.29% on the graph caster change for rear suspension when vertical parallel wheel movement test is employed (Figure 2(f)). If the modelling of the suspension and simulation setup is not going to be wrong, thus the error might come from the experimental process. The error could be from the human factor that contributes during experiment or component setup on the actual test rig.

1. *Vertical parallel wheel movement test*



(a)



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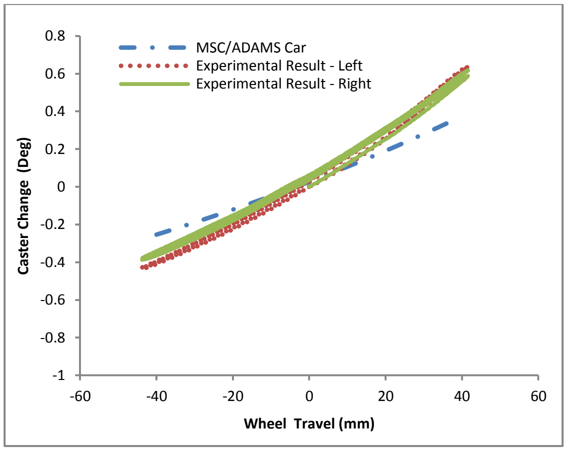

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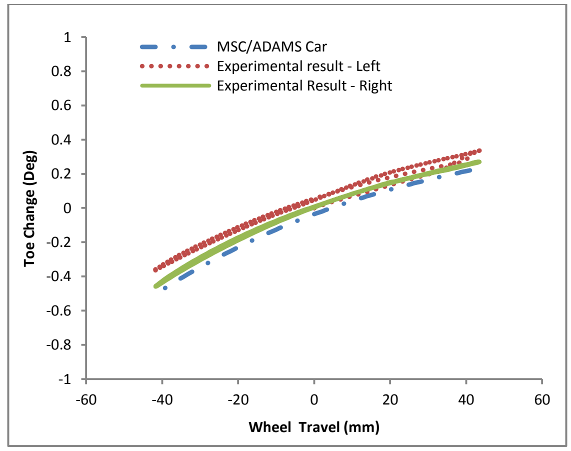

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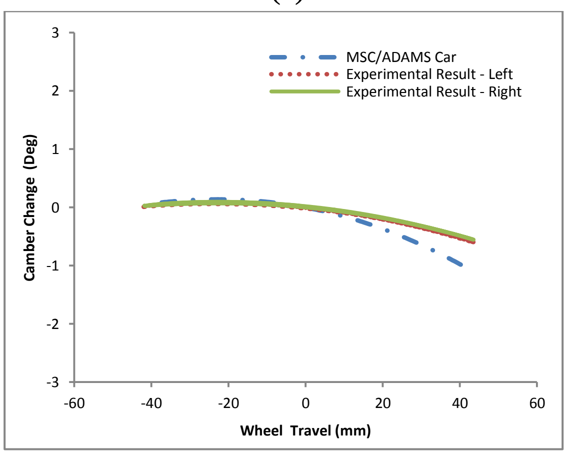

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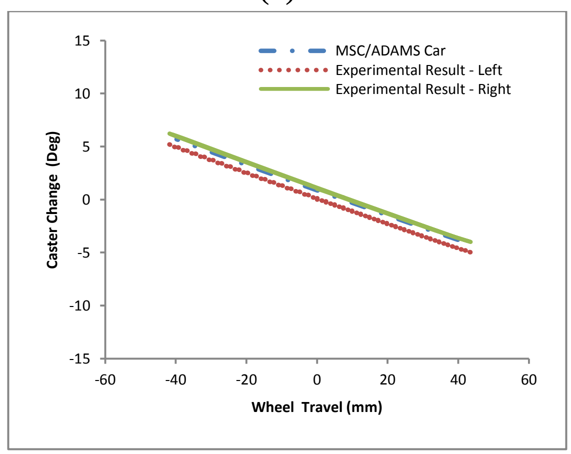
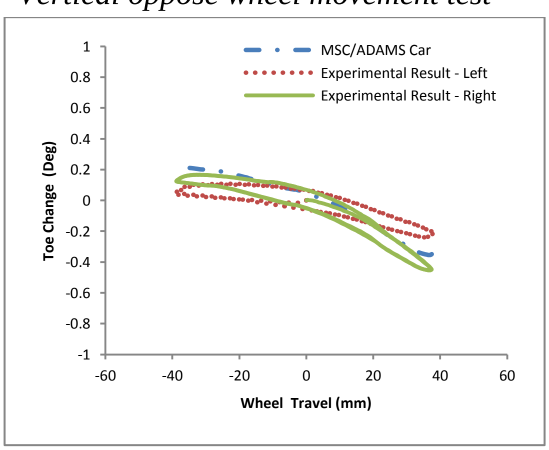


(f)

Figure 4. The left and right suspension system for vertical parallel wheel movement test comparison between experimental and simulation using MSC/ADAMS CAR for front toe change; (a), front camber change; (b) front caster change; (c), rear toe change (d), rear camber change (e) and rear caster change; (f)

2. *Vertical oppose wheel movement test*



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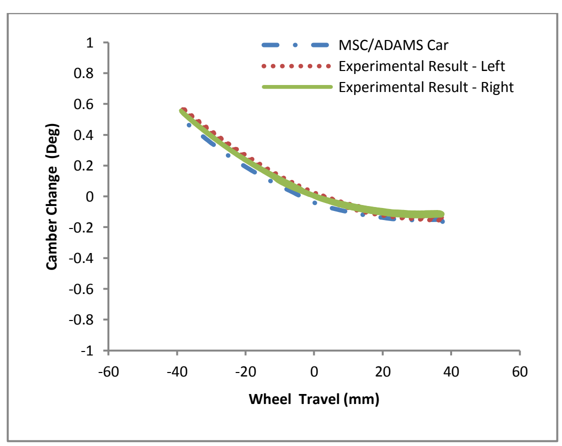

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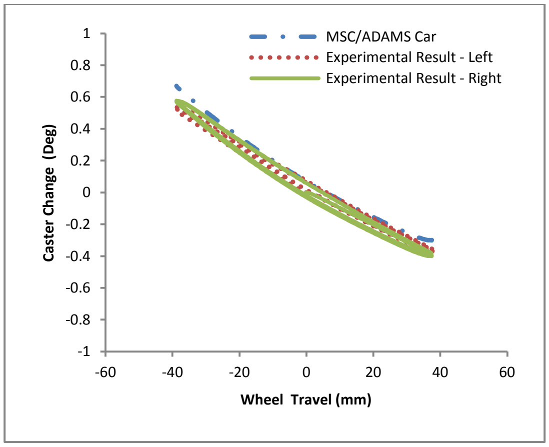

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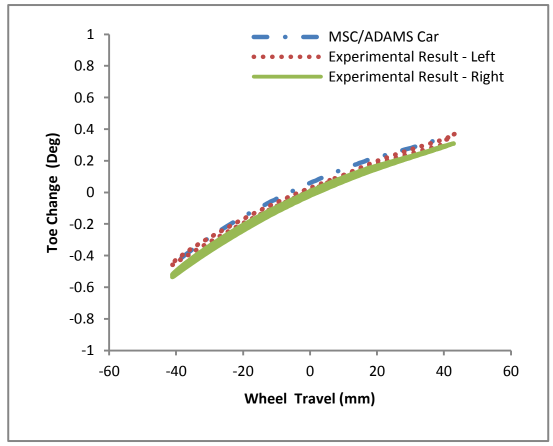

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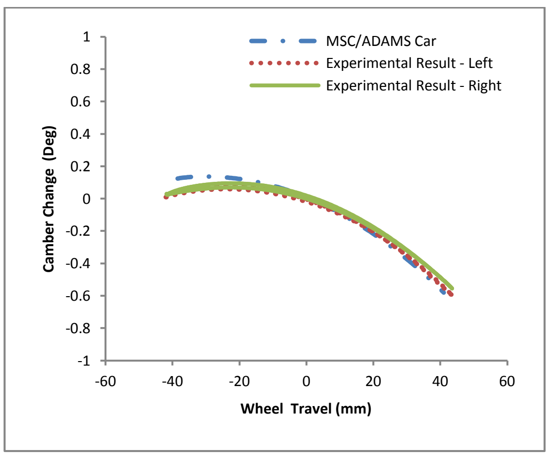

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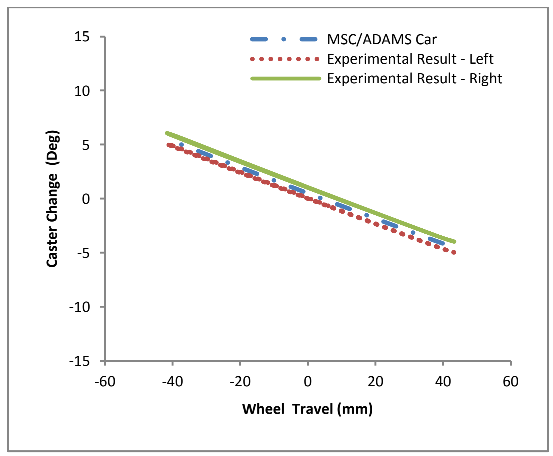

(f)

Figure 5. The left and right suspension system for vertical oppose wheel movement test comparison between experimental and simulation using MSC/ADAMS Car for front toe change; (a), front camber change; (b) front caster change; (c), rear toe change (d), rear camber change (e) and rear caster change; (f)

Table 3. Coefficient of determination, R^2 for linear regression

		Front			Rear		
		Left	Right	MSC/ ADAMS Car	Left	Right	MSC/ ADAMS Car
Vertical parallel movement test	Toe	0.8511	0.9102	0.9299	0.9787	0.9736	0.9800
	Camber	0.8962	0.8878	0.9251	0.8092	0.8052	0.8118
	Caster	0.9872	0.989	0.9667	0.9997	0.9957	0.9968

Vertical Oppose movement test	Toe	0.8232	0.8662	0.9012	0.9775	0.9861	0.9787
	Camber	0.8966	0.9177	0.8960	0.8092	0.8052	0.8511
	Caster	0.9831	0.9910	0.9844	0.9998	0.9978	0.9968

CONCLUSION

The front and rear suspension system of PROTON WRM 44 P0-34 has been modelled and examined based on the kinematic and compliance performance using MSC/ADAMS Car. It was found, both front and rear suspension model were compared and validated with experimental result. Future work aims to the optimization of the suspension using the model to reduce the overall time, cost and workmanship.

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